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Biochemical Application Compilation and Architecture Synthesis for Fault-Tolerant Digital Microfluidic Biochips

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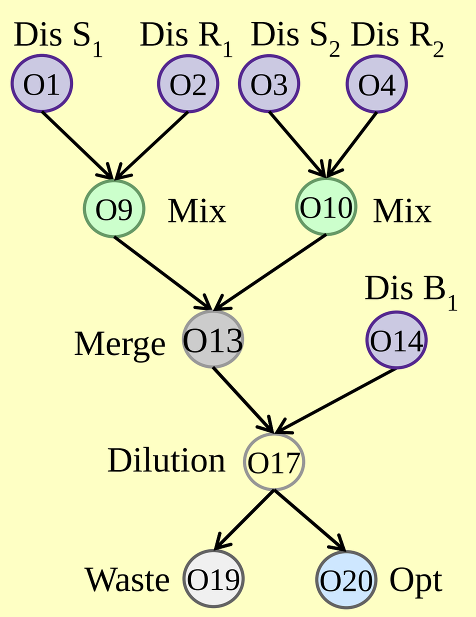
Biochemical Application Compilation and Architecture Synthesis for Fault-Tolerant Digital Microfluidic Biochips

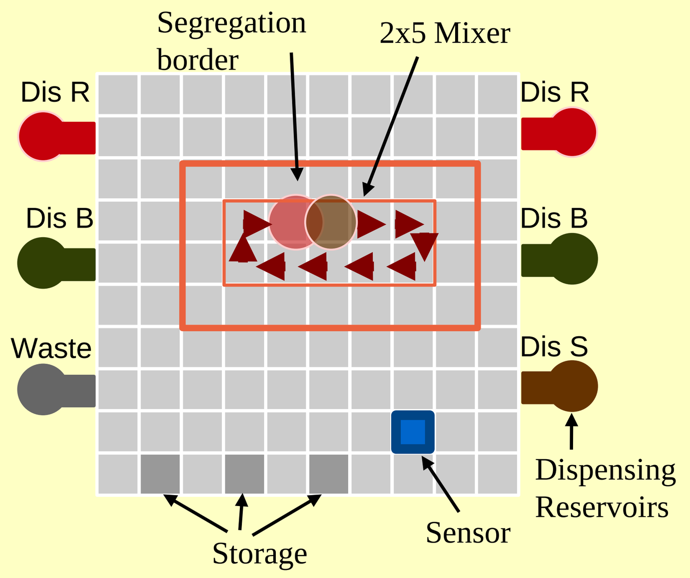
Authors: Mirela Alistar, Paul Pop, Jan Madsen

Biochemical Application Model



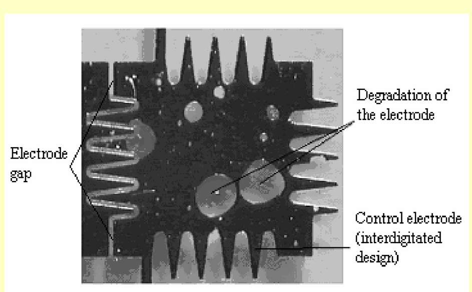
A biochemical protocol is modeled as a directed graph, where the nodes represent the operations and the edges represent the relationship between them. An operation is ready to execute when its inputs have arrived. Examples of operations are: dispensing, mix, dilution, optical detection, merge. Droplets are transmitted through the edges from one operation to its successor operation.

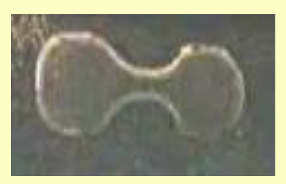
Biochip Architecture Model



A biochip architecture is modeled as an array of electrodes. Operations execute within specified areas called *modules*, which can be placed on any electrodes of the biochip. These architectures are general-purpose and highly reconfigurable.

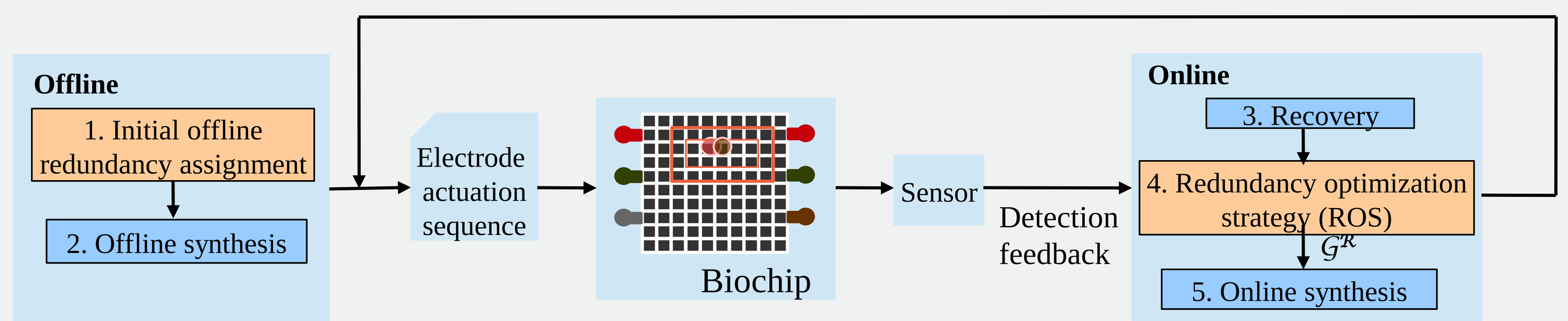
Challenge: Faults



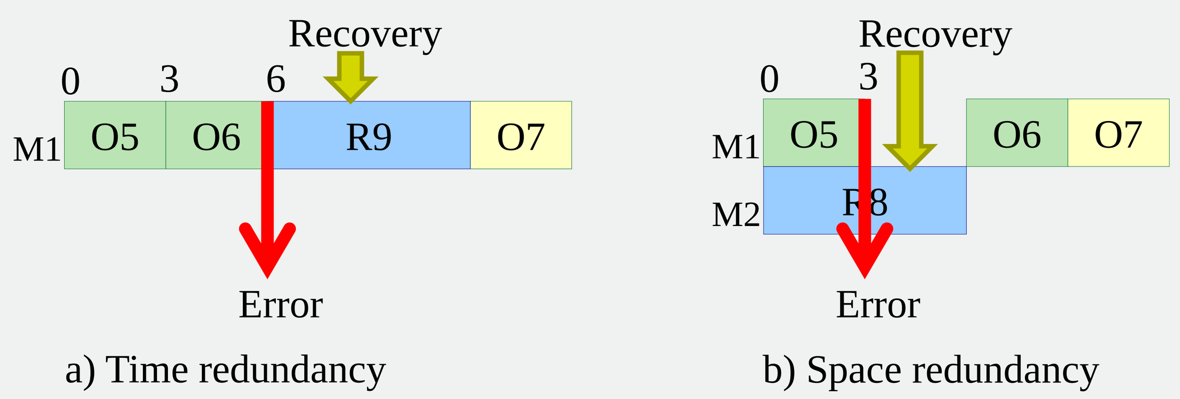


The applications have high sensitivity to volume variations. Faults during runtime, such as an unbalanced split, can compromise the result of the application.

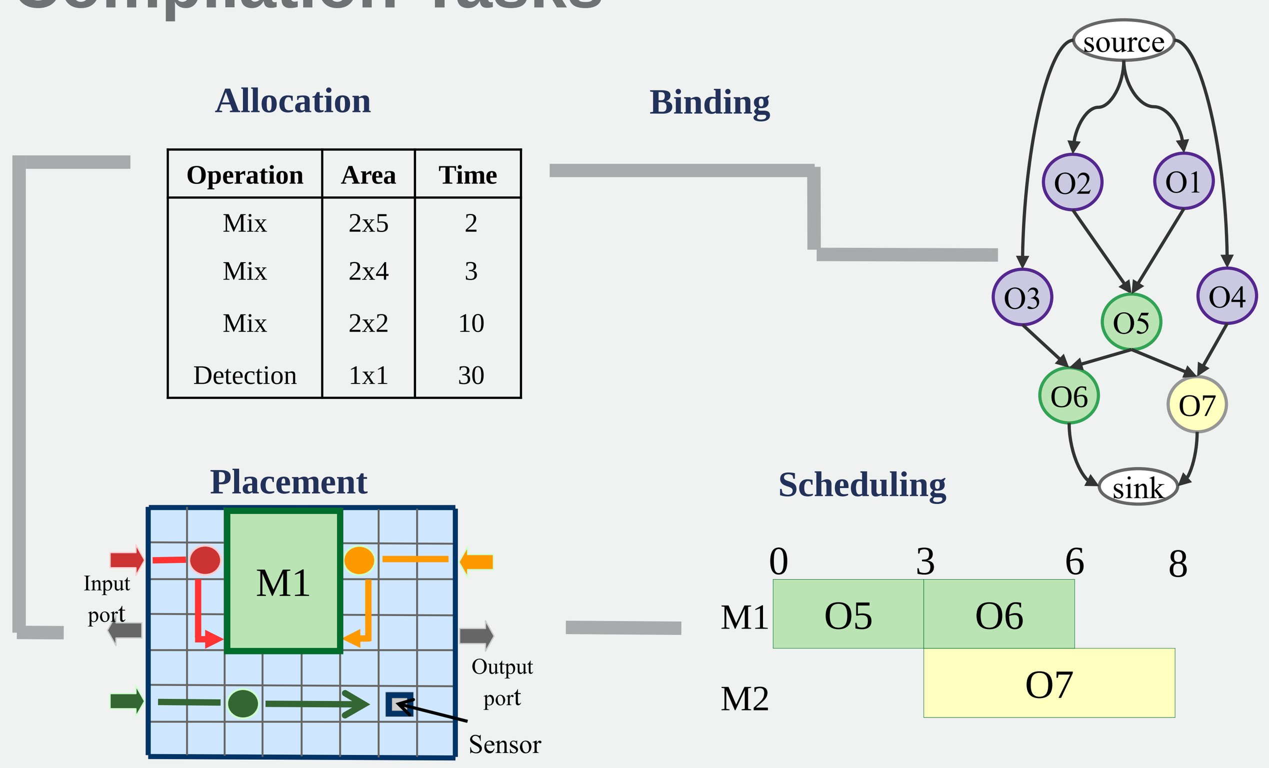
Runtime Compilation



Recovery Methods

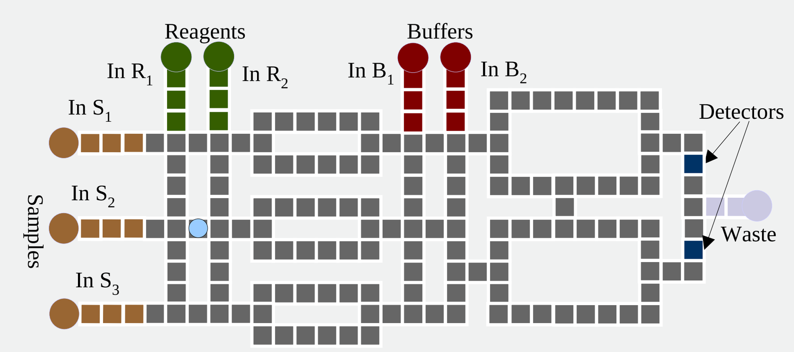


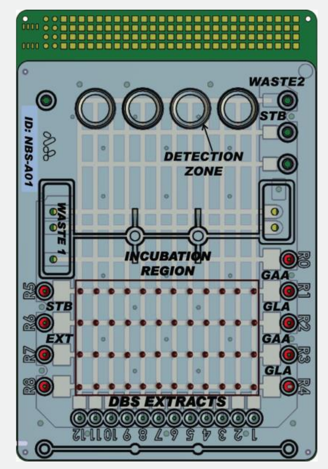
Compilation Tasks

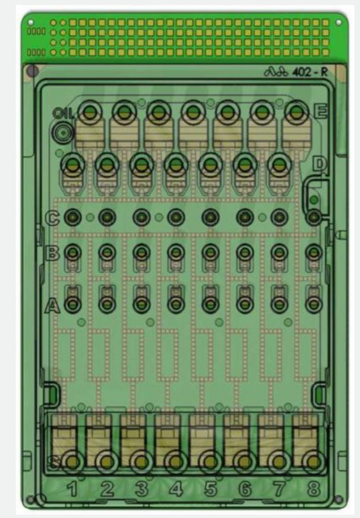


Operation	Area	Time
Mix	2x5	2
Mix	2x4	3
Mix	2x2	10
Detection	1x1	30

Application Specific Architecture







Cost Evaluation

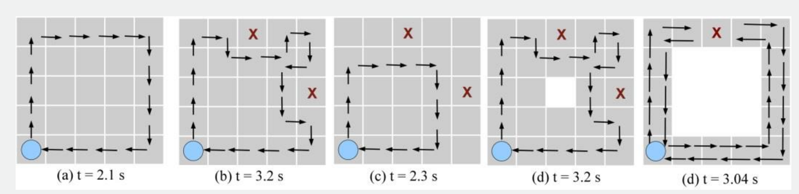
Name	Unit Cost	Dimensions (mm)	Time (s)
Electrode	1	1.5 x 1.5	N/A
Input Reservoir	3	1.5 x 4.5	2
Waste Reservoir	3	1.5 x 4.5	N/A
Capacitive Sensor	1	1.5 x 4.5	0
Optical Sensor	9	4.5 x 4.5	8

$$Cost_{\mathcal{A}} = \sum N_{M_i} \times Cost_{M_i}$$

where

- **A** is the architecture
- $\mathbf{N_{Mi}}$ is the number of components Mi
- $\mathbf{Cost_{Mi}}$ is the cost of the physical component Mi

Problem Formulation



Evaluation of fault-tolerant overhead (faults are marked with X)

- **Given**
  - Biochemical application
  - Deadline requirements
  - Library of components
  - The number *k* of permanent faults
- **Determine** an application-specific architecture **A** , so that
  - the cost is minimized and
  - the application completes within deadline for any occurrence of the *k* permanent faults